

I hereby certify that this paper is being deposited with the United States
Postal Service as Express Mail in an envelope addressed to: Assistant
Commissioner of Patents, Washington, D.C. 20231, on this date.

December 18, 2001
Date

Daijirou
Express Mail Label No.:
EL 846222907 US

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE
APPLICATION FOR LETTERS PATENT

Title : LIQUID CRYSTAL DISPLAY DEVICE

Inventor(s) : Tsutomu KAI
Susumu OKAZAKI
Hongyong ZHANG
Noriyuki OHASHI

10025044-121801

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is based upon and claims priority of Japanese Patent Application No. 2001-101176, filed on March 30, 2001, the contents being incorporated herein by reference.

BACKGROUND OF THE INVENTION

[Field of the Invention]

The present invention relates to a liquid crystal display device and, more specifically, to a liquid crystal display device with switching elements connected to data lines and scanning lines.

[Description of the Related Art]

FIG. 26 shows a structure of a liquid crystal display substrate according to the prior art. A data driver (data line driver) 5 is connected to a pixel region 7 via data lines 3. A gate driver (scanning line driver) 6 is connected to the pixel region 7 via scanning lines 4. The data driver 5 can supply data to the data lines 3. The gate driver 6 can supply scanning signals to the scanning lines 4.

The pixel region 7 has switching elements (TFTs: Thin Film Transistors) 1 and liquid crystal capacitors 2 which are arranged in a two-dimensional matrix. The TFTs 1 are n-channel MOS transistors, of which gates are connected to the scanning lines 4, drains are connected to the data lines 3, and sources

are connected to an electrode 8 on an opposite substrate via the liquid crystal capacitors 2.

A main method of inspecting this liquid crystal display substrate is a method of touching probe pins to ends of each vertical and horizontal lines of the matrix, which needs a large number of probe pins, leading to an expensive inspecting apparatus. This inspection method has a great number of steps because a large number of check terminals are individually inspected. Therefore, the liquid crystal display substrate is subjected to perform display in its finished state as a panel, for a complete inspection, which is a factor causing reduced yields.

FIG. 27 shows another liquid crystal display substrate according to the prior art. On a substrate 900, provided are a shift register 911, analog switches 912, a display part 916, and a gate driver 915. The gate driver 915 is connected to the pixel region 916 via scanning lines G1 to G4 and so on to supply scanning signals to the scanning lines G1 to G4 and so on in response to gate clocks GCLK and gate start pulses GSP.

The pixel region 916 has TFTs 931 and liquid crystal capacitors 932 which are arranged in a two-dimensional matrix. The TFTs 931 are n-channel MOS transistors, of which gates are connected to scanning lines G1 to G4 and so on, drains are connected to data lines D1, D2 and so on, and sources are

connected to an electrode on an opposite substrate via the liquid crystal capacitors 932.

In the analog switches 912, one end of each of input/output terminals is connected to one of data buses V1 to Vn and the other ends are connected to the data lines D1, D2 and so on. The data buses V1 to Vn are connected with a data driver after completion of an inspection and supplied with data.

The shift register 911, capable of m-stage shift, outputs shifted pulses sequentially to control lines Q1 to Qm in response to data clocks DCLK and data start pulses DSP. The control lines Q1 to Qm are connected to control terminals of the analog switches 912 respectively. When the control lines Q1 to Qm are set to be a high level, the analog switches 912 connect the data buses V1 to Vn, and, the data lines D1, D2 and so on respectively.

For the inspection of the liquid crystal display substrate, it is necessary to touch probe pins to terminals of the data buses V1 to Vn. In addition, when the number of the data buses V1 to Vn is increased, high temperature polysilicon needs to be used to operate the liquid crystal display substrate at a high speed, resulting in an expensive liquid crystal display substrate.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a liquid crystal display device capable of being easily inspected in a short time without using a large number of probe pins in an inspecting apparatus.

It is another object of the present invention to inspect an inexpensive liquid crystal display device with ease and in a short time.

According to an aspect of the present invention, a liquid crystal display device is provided, which comprises: a display circuit including data lines and scanning lines arranged in a two-dimensional matrix, and switching elements connected between the data lines and the scanning lines; a first inspection circuit including an inspection voltage input and/or output terminal for inputting and/or outputting an inspection voltage to/from one end of the data line via a first analog switch; and a second inspection circuit including an inspection voltage input and/or output terminal for inputting and/or outputting an inspection voltage to/from the other end of the data line. The display circuit, the first inspection circuit, and the second inspection circuit are provided on one substrate, and the first inspection circuit is separable from the display circuit.

The provision of the first and second inspection circuits on the liquid crystal display substrate

enables, before unitization of the liquid crystal display device, inspection of breaks in the data lines, short circuits between adjacent data lines, breaks in the scanning lines, short circuits between adjacent pixels, short circuits to other signal lines, and the like. The separation of the first inspection circuit after the inspection enables the data driver to be connected to the liquid crystal display substrate, thereby providing a liquid crystal display device at a lower cost.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagram showing a liquid crystal display substrate according to a first embodiment of the present invention;

FIG. 2 is a timing chart showing a first inspection method according to the first embodiment;

FIG. 3 is a timing chart showing a second inspection method according to the first embodiment;

FIG. 4 is a diagram in which a data driver is connected to the liquid crystal display substrate according to the first embodiment;

FIG. 5 is a diagram showing a liquid crystal display substrate according to a second embodiment of the present invention;

FIG. 6 is a diagram showing a liquid crystal display substrate according to a third embodiment of the present invention;

FIG. 7 is a timing chart showing a first inspection method according to the third embodiment;

FIG. 8 is a timing chart showing a second inspection method according to the third embodiment;

FIG. 9 is another timing chart showing the second inspection method according to the third embodiment;

FIG. 10 is a diagram showing a liquid crystal display substrate according to a fourth embodiment of the present invention;

FIG. 11 is a diagram showing a liquid crystal display substrate according to a fifth embodiment of the present invention;

FIG. 12 is a diagram showing a liquid crystal display substrate according to a sixth embodiment of the present invention;

FIG. 13 is a diagram showing a liquid crystal display substrate according to a seventh embodiment of the present invention;

FIG. 14 is a diagram showing a liquid crystal display substrate according to an eighth embodiment of the present invention;

FIG. 15 is a diagram showing a liquid crystal display substrate according to a ninth embodiment of the present invention;

FIG. 16 is a diagram showing a liquid crystal display substrate according to a tenth embodiment of the present invention;

FIG. 17 is a diagram showing a liquid crystal display substrate according to an eleventh embodiment of the present invention;

FIG. 18 is a diagram showing a liquid crystal display substrate according to a twelfth embodiment of the present invention;

FIG. 19 is a diagram showing a liquid crystal display substrate according to a thirteenth embodiment of the present invention;

FIG. 20 is a diagram showing a liquid crystal display substrate according to a fourteenth embodiment of the present invention;

FIG. 21 is a diagram showing a liquid crystal display substrate according to a fifteenth embodiment of the present invention;

FIG. 22 is a diagram showing a liquid crystal display substrate according to a sixteenth embodiment of the present invention;

FIG. 23 is a diagram showing a liquid crystal display device according to a seventeenth embodiment of the present invention;

FIG. 24 is a diagram showing a liquid crystal display device according to an eighteenth embodiment of the present invention;

FIG. 25 is a diagram showing a liquid crystal display device according to a nineteenth embodiment of the present invention;

FIG. 26 is a diagram showing a liquid crystal display substrate according to the prior art; and

FIG. 27 is a diagram showing another liquid crystal display substrate according to the prior art.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

-First Embodiment-

FIG. 1 shows a liquid crystal display substrate 100 according to the first embodiment of the present invention. A first inspection circuit 101, a display circuit 103, and a second inspection circuit 102 are provided on one glass substrate 100. The first inspection circuit 101 is separable from the display circuit 103 at a cutting line 121. The second inspection circuit 102 is separable from the display circuit 103 at a cutting line 122.

The display circuit 103 has a gate driver 115, a pixel region 116 and analog switches 112. The gate driver 115 is connected to the pixel region 116 through scanning lines G1 to Gx to supply scanning signals to the scanning lines G1 to Gx in response to gate clocks GCLK and gate start pulses GSP.

The pixel region 116 has TFTs 131 and liquid crystal capacitors 132 which are arranged in a two-dimensional matrix. The TFTs 131 are n-channel MOS transistors, of which gates are connected to the scanning lines G1 to Gx, drains are connected to data lines D1 to D3 and so on, and sources (pixel

electrodes) are connected to an electrode on an opposite substrate via the liquid crystal capacitors 132.

In the analog switches 112, one end of each of input/output terminals is connected to one of data lines D1a to D3a and so on, and the other ends are connected to the data lines D1 to D3 and so on. Block selection signal lines BSEL1 to BSELM are connected to control terminals of the analog switches 112 respectively. The analog switches 112 connect the data lines D1a to D3a and so on, and, the data lines D1 to D3 and so on respectively when the block selection signal lines BSEL1 to BSELM are set to a high level.

The first inspection circuit 101 has a shift register 111 and analog switches 113. In the analog switches 113, one end of each of input/output terminals is connected alternately to signal lines V1 and V2, and the other ends are connected to the data lines D1a to D3a and so on. The shift register 111, capable of n-stage shift, outputs shifted pulses sequentially to control lines Q1 to Qn in response to data clocks SCLK and data start pulses SSP as shown in FIG. 2. The control lines Q1 to Qn are connected to control terminals of the analog switches 113 respectively. The analog switches 113 connect the signal lines V1 and V2, and, the data lines D1a to

D3a and so on respectively when the control lines Q1 to Qn are set to a high level.

The second inspection circuit 102 has analog switches 114. In the analog switches 114, one end of each of input/output terminals is connected to one of the data lines D1 to D3 and so on, and the other ends are connected to a signal line V3. A control line ON4 is connected to control terminals of the analog switches 114. The analog switches 114 connect the data lines D1 to D3 and so on, and, the signal line V3 respectively when the control line ON4 is set to a high level.

As shown in FIG. 2, while the control line ON4 is at the high level, pulses are outputted sequentially to the block selection signal lines BSEL1 to BSELn. While each of the block selection signal lines BSEL1 to BSELn is at the high level, pulses are outputted sequentially to the control lines Q1 to Qn.

First, an inspection signal is inputted to the signal line V3. When the control line ON4 is set to the high level, the analog switches 114 turn on to connect the data lines D1 to D3 and the signal line V3. When the block selection signal line BSEL1 is set to the high level, n analog switches 112 in a first block from the left side turn on to connect the data lines D1a to D3a and so on, and, the data lines D1 to D3 and so on. When the control line Q1 is set to the high level, the analog switch 113 at the left

end turns on to connect the signal line V1 and the data line D1a. Similarly the control lines Q2 to Qn are sequentially set to the high level.

By detecting outputs of the signal lines V1 and V2, inspection can be performed. When the control line Q1 is set to the high level, if the inspection signal inputted to the signal line V3 can be detected in the signal line V1, the data lines D1 and D1a can be verified as not broken, and if the signal line V1 is open, the data line D1 or D1a can be verified as broken. Similarly, when the control line Q2 is set to the high level, if the inspection signal inputted to the signal line V3 can be detected in the signal line V2, the data lines D2 and D2a can be verified as not broken, and if the signal line V2 is open, the data line D2 or D2a can be verified as broken. In the same manner, whether or not other data lines D3 and D3a and so on are broken can be verified. According to this embodiment, the above break in the line can be detected as a defect point.

Next, another inspection method is explained. As shown in FIG. 3, the block selection signal lines BSEL1 to BSELn are set to a low level to turn off the analog switches 112. Then, the cycle of the start pulse SSP is increased to be twice that of the clock SCLK. As a result, there is a period during which both the control lines Q1 and Q2 are at the high level. During the period, an inspection signal is

inputted to the signal line V1 to detect an output of the signal line V2. If the inspection signal inputted to the signal line V1 is detected in the signal line V2, the data lines D1a and D2a can be verified as short-circuiting to each other, and if the signal line V2 is open, the data lines D1a and D2a can be verified as not short-circuiting to each other. Further, during a period during which both the control lines Q2 and Q3 are at the high level, the existence of a short-circuit between the data lines D2a and D3a can be verified. Similarly, short circuits between other adjacent data lines can be checked. According to this embodiment, the above short circuit can be detected as a defect point.

Although the case of one shift register 111 is explained in this embodiment, two or more shift registers 111 may be provided. Further, two signal lines V1 and V2 are provided in the first inspection circuit 101, but only one signal line may be provided for inspection of only a break in a line. Further, by increasing the number of the two signal lines V1 and V2, the shift stages of the shift register 111 can be decreased, and even short circuits between non-adjacent data lines D1a to D3a and so on between the analog switches 112 and 113 can be checked. Furthermore, if a signal on a power supply, ground, or other signal lines is detected in the signal line

V2, it can be verified that a short circuit occurs with respect to the power supply or the like.

After the inspection, the first inspection circuit 101 and the second inspection circuit 102 are separated from the display circuit 102 at the cutting lines 121 and 122. Then, as shown in FIG. 4, output lines Q1 to Qn of a data driver 401 are connected to the data lines D1a to D3a and so on of the display circuit 103 in unitizing the liquid crystal display device. The data driver 401 receives clocks DCLK, start pulses DSP, latch pulses LP and data R, G, B and outputs data to the output lines Q1 to Qn. This enables the liquid crystal display device to perform normal operation.

The second inspection circuit 102 is not necessarily separated from the display circuit 103. When the second inspection circuit 102 is not separated, the analog switches 114 are preferably always turned off during normal operation. Further, the second inspection circuit 102 can be used as a precharge function during normal operation. More specifically, the data line D1 and so on can be precharged by inputting a voltage to the signal line V3 of the second inspection circuit 102 before the data is outputted to the output lines Q1 to Qn of the data driver 401.

In this embodiment, since the liquid crystal display substrate is capable of display even if it is

operated at not such high speed as that by the prior art in FIG. 27, an inexpensive liquid crystal display substrate can be fabricated using low temperature polysilicon.

-Second Embodiment-

FIG. 5 shows the liquid crystal display substrate 100 according to the second embodiment of the present invention. The second embodiment differs from the first embodiment in that the second inspection circuit is included in the display circuit 103 and signal lines V3 and V4 are alternately connected to the other ends of the input/output terminals of the analog switches 114, and the other points are the same.

Different inspection signals are inputted to the signal lines V3 and V4 for operation at the timing in FIG. 3 as in the first embodiment. In this event, if, for example, the data lines D1 and D2 short-circuit to each other, or the data lines D1a and D2a short-circuit to each other, the same signal is detected in the signal lines V1 and V2. On the other hand, if the data lines D1 and D2 do not short-circuit to each other and the data lines D1a and D2a do not short-circuit to each other, the inspection signal inputted to the signal line V3 is detected in the signal line V1, and the inspection signal inputted to the signal line V4 is detected in the signal line V2. The

existence of a short circuit between adjacent data lines can be checked as described above.

Further, the signal lines V3 and V4 can be used as precharge functions during normal operation. Polarities of data on the data lines D1 to D3 and so on are preferably opposite, positive and negative, between even-numbered lines and odd-numbered lines to prevent image flicker and the like. In this event, the data lines D1 to D3 and so on can be precharged by inputting voltages with opposite polarities to the signal lines V3 and V4 before the data is outputted to the output lines Q1 to Qn of the data driver 401.

-Third Embodiment-

FIG. 6 shows the liquid crystal display substrate 100 according to the third embodiment of the present invention. The third embodiment differs from the second embodiment in that n-channel MOS transistors 601 and capacitors (condensers) 602 are provided, and the other points are the same.

In the transistors 601, gates are connected to the scanning lines G1 to Gx respectively, drains are connected to a common signal line Vmon, and sources are connected to a common voltage terminal via the capacitors 602.

FIG. 7 is a timing chart showing the inspection method. The gate driver 115 outputs the scanning signals sequentially to the scanning lines G1 to Gx in response to clocks GCLK and start pulse GSP.

During a period 701 of the output, an inspection voltage V_a is inputted to the signal line V_{mon} . The transistors 601 turn on when the scanning lines G_1 to G_x are set to the high level respectively to store the inspection voltage V_a in the capacitors 602.

Next, the start pulse GSP is inputted again to output the scanning signals sequentially to the scanning lines G_1 to G_x . During a period 702 of the output, an output of the signal line V_{mon} is detected. If the inspection voltage V_a is detected in the signal line V_{mon} while each of the scanning lines G_1 to G_x is at the high level, all of the scanning lines G_1 to G_x can be verified as not broken. On the other hand, if there is a period during which the inspection voltage V_a is not detected in the signal line V_{mon} in the period 702, the scanning line corresponding to the period can be verified as broken. According to this embodiment, a break in the scanning lines G_1 to G_x can be detected as a defect point.

FIG. 8 is a timing chart showing another inspection method which is performed after the above-described inspection. The clock GCLK, the start pulse GSP, and the scanning lines G_1 to G_x are the same as those in FIG. 7. Periods 801 and 802 are periods during which the scanning lines G_1 and G_2 are at the high level respectively. During the periods 801 and 802, processing shown in FIG. 9 is performed respectively. Also in periods during which other

scanning lines G3 to Gx are set to the high level, processing is similarly performed at the timing shown in FIG. 9.

In FIG. 9, the clock SCLK, the start pulse SSP, and the control lines Q1 to Qn are the same as those in FIG. 3. While the control line ON4 is at the high level, the block selection signal lines BSEL1 to BSELM are sequentially set to the high level. While each of the block selection signal lines BSEL1 to BSELM is at the high level, the control lines Q1 to Qn sequentially turn to the high level.

For example, both the control lines Q1 and Q2 turn to the high level as shown in FIG. 9 while the scanning line G1 is at the high level as shown in FIG. 8. The analog switches 113 connect the signal line V1 and the data line D1a, and the signal line V2 and the data line D2a. Since the block selection signal line BSEL1 is at the high level in this event, the analog switches 112 connect the data lines D1a and D1, and the data lines D2a and D2. Since the control line ON4 is at the high level, the analog switches 114 connect the data line D1 and the signal line V3, and the data line D2 and the signal line V4.

Similarly to the second embodiment, different inspection signals are inputted to the signal lines V3 and V4. If the lines G1 and D1 do not short-circuit to each other, and the lines G2 and D2 do not short-circuit to each other, the inspection signals

inputted to the signal lines V3 and V4 can be detected in the signal lines V1 and V2 respectively. On the other hand, if the lines G1 and D1 short-circuit to each other, or the lines G2 and D2 short-circuit to each other, voltages affected by the scanning line G1 or G2 are detected in the signal lines V1 and V2. The existence of a short circuit between adjacent pixels can also be checked at that time. According to this embodiment, a defect such as a short circuit between the scanning line and the data line and a short circuit between adjacent pixels can be detected.

Through the above-described inspection, a line defect of the liquid crystal display substrate can be inspected. Thereafter, a point defect of a pixel corresponding to each TFT (switching element) 131 of the display circuit 103 is inspected. This enables inspection of both the line defect and the point defect.

As described above, according to the first to third embodiments, the provision of the first and second inspection circuits together with the display circuit on the liquid crystal display substrate enables, before unitization of the liquid crystal display device, inspection of the existence of defects such as breaks in the data lines, short circuits between adjacent data lines, short circuits between the data lines between the analog switches

112 and the analog switches 113, breaks in the scanning lines, short circuits between adjacent pixels, short circuits to other signal lines, and the like. The separation of the first inspection circuit 101 after the inspection enables the data driver 401 to be connected to the display circuit 103, thereby providing a liquid crystal display device at a lower cost.

-Fourth Embodiment-

FIG. 10 shows a liquid crystal display substrate according to the fourth embodiment of the present invention. In a pixel region 7, gates of TFTs (n-channel MOS transistors) 1 are connected to scanning lines 4, drains are connected to data lines 3, and sources (pixel electrodes) are connected to an electrode 8 on an opposite substrate via liquid crystal capacitors 2. Between the pixel region 7 and a gate driver 6, and between the pixel region 7 and a data driver 5, inspection switching elements (n-channel MOS transistors) 9 are provided. Gates of the inspection switching elements 9 are connected to the scanning lines 4 or the data lines 3. In the switching elements 9, sources are connected to the ground via capacitors 30 and drains are connected to a common inspection terminal 10 via a buffer 31 or 32. The buffers 31 and 32 constitute a bidirectional switch. A control terminal of the buffer 32 is directly connected to a terminal 34. A control

terminal of the buffer 31 is connected to the terminal 34 via an inverter 33. A controller 35 inputs a high level to the terminal 34 to make the inspection terminal 10 an input terminal, and inputs a low level to the terminal 34 to make the inspection terminal 10 an output terminal.

The data driver 5, a data supply circuit for supplying data to the data lines 3, may be analog switches. The gate driver 6 can supply scanning signals to the scanning lines 4.

Next, the inspection method is explained. The gate driver 6 or the data driver 5 first outputs a signal for turning on the inspection switching element 9. During a period during which the inspection switching element 9 is on, the controller 35 inputs an inspection signal to the inspection terminal 10 to charge (preset) the capacitor 30. The inspection switching element 9 is turned on again to detect from the inspection terminal 10 the voltage charged in the capacitor 30. If the inspection voltage can be detected, it can be judged that the gate driver 6 or the data driver 5 is operating normally, and that the scanning line 4 or the data line 3 from the gate driver 6 or the data driver 5 to the pixel region 7 is not broken and is acceptable. By repeating this inspection from the first line to the last line of the scanning lines 4 and the data lines 3 respectively, failures of the gate driver 6

and the data driver 5, and points and the number of breaks in the scanning lines 4 and the data lines 3, can be inspected.

Although the inspection switching elements 9 are arranged on the input sides (left and upper sides) of the pixel region 7 in this embodiment, they may be arranged on the output sides (right and lower sides). In the case of the arrangement on the output sides, breaks in the scanning lines 4 and the data lines 3 in the pixel region 7 can also be inspected. The aforementioned capacitors 30 may be separately provided for the respective inspection switching elements 9, or one capacitor 30 may be shared among the inspection switching elements 9. Alternatively, the capacitors 30 for the inspection switching elements 9 may be connected in parallel.

-Fifth Embodiment-

FIG. 11 shows a liquid crystal display substrate according to the fifth embodiment of the present invention. The fifth embodiment differs from the fourth embodiment in that a reset switch (n-channel MOS transistor) 11 is provided, and the other points are the same. In the reset switch 11, a gate is connected to an ON-OFF signal terminal 12, a drain is connected to a reset data input terminal 13, and a source is connected to each source of the inspection switching elements 9.

For the inspection, the ON-OFF signal terminal 12 is first set to a high level to turn on the reset switch 11, and the reset data input terminal 13 is set to the ground level to remove the charges in the capacitors 30. Then, the inspection shown in the fourth embodiment is performed. The reset of the capacitors 30 enables appropriate detection of the inspection voltage, resulting in improved accuracy of inspection.

-Sixth Embodiment-

FIG. 12 shows a liquid crystal display substrate according to the sixth embodiment of the present invention. Only the points of the sixth embodiment differing from the fifth embodiment are explained. The inspection switching elements 9 are provided not only at the upper and left sides of the pixel region 7, but also at the right and lower sides. More specifically, the inspection switching elements 9 are provided at the output end of the pixel region 7 with respect to the gate driver 6 and at the output end of the pixel region 7 with respect to the data driver 5. In the inspection switching elements 9, similarly to the above explanation, the gates are connected to the scanning lines 4 or the data lines 3, the drains are connected to the inspection terminals 10 via the buffer 31 or 32, and the sources are connected to the ground via the capacitors 30. The reset data input terminal 13 is connected to the sources of the

inspection switching elements 9 via the reset switch 11.

The same inspection as that in the fifth embodiment is performed. If the charge stored in the capacitor 30 can normally be detected from the inspection terminals 10 at the input sides (left and upper sides) of the pixel region 7, it can be judged that the gate driver 6 and the data driver 5 are operating normally, and that the scanning line 4 and the data line 3 from the gate driver 6 or the data driver 5 to the pixel region 7 are not broken and are acceptable.

If the charge stored in the capacitor 30 can normally be detected from the inspection terminals 10 at the output sides (right and lower sides) of the pixel region 7, it can be judged that the scanning line 4 and the data line 3 in the pixel region 7 are not broken and are acceptable.

By repeating this inspection from the first line to the last line of the gate driver 6 and the data driver 5, failures of the gate driver 6 and/or the data driver 5, and points and the number of breaks in the scanning lines 4 and/or the data lines 3, can be inspected.

-Seventh Embodiment-

FIG. 13 shows a liquid crystal display substrate according to the seventh embodiment of the present invention. The seventh embodiment shows a case in

which the inspection switching elements 9 in the fourth embodiment (FIG. 10) are inspection pixels 15. In other words, the inspection switching elements 9 in this case are the same TFTs as the TFTs 1 in the pixel region 7. The sources (pixel electrodes) of the inspection switching elements 9 are connected to the electrode 8 on the opposite substrate via the liquid crystal capacitors 2.

Although the capacitors 30 are charged with the inspection voltage in the fourth to sixth embodiments, the liquid crystal capacitors 2 are charged with the inspection voltage in this embodiment. The liquid crystal capacitor 2 has a large storable capacity as compared to the capacitor 30, which facilitates judgement at the time of inspection. During normal operation after the inspection, black data is written in the inspection pixels 15, which causes a decrease in contrast, and therefore the inspection pixels 15 are preferably shielded from light in advance.

-Eighth Embodiment-

FIG. 14 shows a liquid crystal display substrate according to the eighth embodiment of the present invention. The point of the eighth embodiment differing from the seventh embodiment is explained. The inspection switching elements 9 which are the inspection pixels 15 are provided, as in the sixth embodiment (FIG. 12), not only at the input sides

(upper and left sides) of the pixel region 7 but also at the output sides (right and lower sides).

If the charge stored in the liquid crystal capacitor 2 can normally be detected from the inspection terminals 10 at the input sides (left and upper sides) of the pixel region 7, it can be judged that the gate driver 6 and the data driver 5 are operating normally, and that the scanning line 4 and the data line 3 from the gate driver 6 or the data driver 5 to the pixel region 7 are not broken and are acceptable.

If the charge stored in the liquid crystal capacitor 2 can normally be detected from the inspection terminals 10 at the output sides (right and lower sides) of the pixel region 7, it can be judged that the scanning line 4 and the data line 3 in the pixel region 7 are not broken and are acceptable.

-Ninth Embodiment-

FIG. 15 shows a liquid crystal display substrate according to the ninth embodiment of the present invention. The ninth embodiment differs from the seventh embodiment in that the reset switch (n-channel MOS transistor) 11 is provided as in the fifth embodiment (FIG. 11), and the other points are the same. In the reset switch 11, the gate is connected to the ON-OFF signal terminal 12, the drain is connected to the reset data input terminal 13, and

the source is connected to each source of the inspection switching elements 9 which are the inspection pixels.

For the inspection, the ON-OFF signal terminal 12 is first set to a high level to turn on the reset switch 11, and the reset data input terminal 13 is set to the ground level to remove the charges in the liquid crystal capacitors 2. Then, the inspection shown in the fourth embodiment is performed. The reset of the liquid crystal capacitors 2 enables improvement in accuracy of inspection.

-Tenth Embodiment-

FIG. 16 shows a liquid crystal display substrate according to the tenth embodiment of the present invention. The tenth embodiment differs from the eighth embodiment (FIG. 14) in that the reset switches (n-channel MOS transistors) 11 are provided as in the ninth embodiment (FIG. 15), and the other points are the same. For the inspection, the ON-OFF signal terminals 12 are first set to a high level to turn on the reset switches 11, and the reset data input terminals 13 are set to the ground level to remove the charges in the liquid crystal capacitors 2. Then, the inspection shown in the fourth embodiment is performed.

-Eleventh Embodiment-

FIG. 17 shows a liquid crystal display substrate according to the eleventh embodiment of the present

invention. The point of the eleventh embodiment differing from the ninth embodiment (FIG. 15) is explained. The inspection switching elements 9 which are the inspection pixels 15 are provided between the pixel region 7 and the gate driver 6 and between the pixel region 7 and the data driver 5. In the inspection switching elements 9, the gates are connected to the scanning lines 4 or the data lines 3, the drains are connected to the data lines 3 or the scanning lines 4, and the sources are connected to the electrode 8 on the opposite substrate via the liquid crystal capacitors 2. More specifically, in the inspection switching element 9, if the scanning line 4 is connected to the gate, the data line 3 is connected to the drain, and if the data line 3 is connected to the gate, the scanning line 4 is connected to the drain.

To the sources of the inspection switching elements 9 which are the inspection pixels 15, the reset data input terminal 13 is connected via the reset switch 11, and an inspection terminal 17 is connected via an inspection switch 16. The inspection switch 16 corresponds to the buffer 31 of the ninth embodiment (FIG. 15), and the inspection terminal 17 corresponds to the inspection terminal 10 of the ninth embodiment.

The reset switch 11, differing from that of the ninth embodiment, has a CMOS structure in which

sources and drains of an n-channel MOS transistor 11a and a p-channel MOS transistor 11b are interconnected. A terminal 44 is connected to a gate of the transistor 11b via an inverter 43 and directly to a gate of the transistor 11a. When the terminal 44 is set to a high level, the reset switch 11 turns on, and when set at a low level, the reset switch 11 turns off.

The inspection switch 16 has a CMOS structure in which sources and drains of an n-channel MOS transistor 16a and a p-channel MOS transistor 16b are interconnected. A terminal 42 is connected to a gate of the transistor 16b via an inverter 41 and directly to a gate of the transistor 16a. When the terminal 42 is set to a high level, the inspection switch 16 turns on, and when set at a low level, the inspection switch 16 turns off.

Next, the inspection method is explained. The reset switch 11 is first turned on, and the data input terminal 13 is set at 0V to remove the charges in the liquid crystal capacitors 2. Then, data is written in the liquid crystal capacitor 2 of the inspection switching element 9 which are the inspection pixel 15 from the gate driver 6 or the data driver 5. Subsequently, the inspection switch 16 is turned on to read the data written in the liquid crystal capacitor 2 from the inspection terminal 17. If the written data can be detected, it

can be judged that the gate driver 6 or the data driver 5 is operating normally, and that the scanning line 4 and the data line 3 from the gate driver 6 or the data driver 5 to the pixel region 7 are not broken and are acceptable. By repeating this inspection from the first line to the last line of the gate driver 6 and the data driver 5, failures of the gate driver 6 and/or the data driver 5, and points and the number of breaks in the scanning lines 4 and/or the data lines 3, can be inspected.

Incidentally, the reset of the liquid crystal capacitors 2 and the preset of the inspection voltage may be performed by supplying data thereto from the data driver 5.

-Twelfth Embodiment-

FIG. 18 shows a liquid crystal display substrate according to the twelfth embodiment of the present invention. The point of the twelfth embodiment differing from the eleventh embodiment is explained. The inspection switching elements 9 which are the inspection pixels 15 are provided not only at the input sides (upper and left sides) but also at the output sides (right and lower sides) as in the eighth embodiment (FIG. 14).

If the charge stored in the liquid crystal capacitor 2 can normally be detected from the inspection terminal 17 at the input sides (left and upper sides) of the pixel region 7, it can be judged

that the gate driver 6 and the data driver 5 are operating normally, and that the scanning line 4 and the data line 3 from the gate driver 6 or the data driver 5 to the pixel region 7 are not broken and are acceptable.

If the charge stored in the liquid crystal capacitor 2 can normally be detected from the inspection terminal 17 at the output sides (right and lower sides) of the pixel region 7, it can be judged that the scanning line 4 and the data line 3 in the pixel region 7 are not broken and are acceptable.

Incidentally, the reset of the liquid crystal capacitors 2 and the preset of the inspection voltage may be performed by writing data from the gate driver 6 or the data driver 5.

-Thirteenth Embodiment-

FIG. 19 shows a liquid crystal display substrate according to the thirteenth embodiment of the present invention. The point of the thirteenth embodiment differing from the tenth embodiment (FIG. 16) is explained. Although the inspection terminals 10 are provided separately for groups of the inspection switching elements 9 in four areas on the upper and lower and left and right sides of the pixel region 7 in the tenth embodiment, the inspection terminal 10 is provided which is shared between the groups of the inspection switching elements 9 in two areas on the left and lower sides of the pixel region 7, and the

inspection terminal 10 is provided which is shared between the groups of the inspection switching elements 9 in two areas on the right and upper sides of the pixel region 7 in the thirteenth embodiment. According to this embodiment, the groups of the switching elements 9 in two areas can be controlled by the inspection terminal 10 and the reset data input terminal 13 each.

-Fourteenth Embodiment-

FIG. 20 shows a liquid crystal display substrate according to the fourteenth embodiment of the present invention. The point of the fourteenth embodiment differing from the thirteenth embodiment (FIG. 19) is explained. The inspection terminals 10 and the reset data input terminals 13 are provided which are shared between the groups of the inspection switching elements 9 in the two areas on the left and lower sides of the pixel region 7, and between the groups of the inspection switching elements 9 in the two areas on the right and upper sides of the pixel region 7 respectively in the thirteenth embodiment. In the fourteenth embodiment, the inspection terminal 10 and the reset data input terminal 13 are provided which are shared between the groups of the inspection switching elements 9 in the four areas on the upper and lower and left and right sides of the pixel region 7. According to this embodiment, the groups of the switching elements 9 in the four areas can be

controlled by the inspection terminal 10 and the reset data input terminal 13 each.

-Fifteenth Embodiment-

FIG. 21 shows a liquid crystal display substrate according to the fifteenth embodiment of the present invention. In the pixel region 7, the gates of the TFTs 1 are connected to the scanning lines 4, the drains are connected to the data lines 3, and the sources (pixel electrodes) are connected to the electrode 8 on the opposite substrate via the liquid crystal capacitors 2. The gate driver 6 outputs scanning signals to the scanning lines 4, and the data driver 5 outputs data to the data lines 3.

In this embodiment, TFTs 1a in a column at the left end in the pixel region 7 are used as inspection switching elements. To sources of the TFTs 1a, the electrode 8 on the opposite substrate is connected via liquid crystal capacitors 2a. To the data line 3 at the left end connected to the data driver 5, the reset data input terminal 13 is connected via the reset switch 11, and the inspection terminal 17 is connected via the inspection switch 16 as in the eleventh embodiment (FIG. 17).

The inspection method is explained. The charges in the liquid crystal capacitors 2a are removed through use of the reset switch 11 as in the eleventh embodiment. Then, the gate driver 6 turns on the TFT 1a to be inspected. During a period during which the

10025044-121301

TFT 1a is on, the data driver 5 supplies voltage to the liquid crystal capacitor 2a to charge it. Subsequently, the inspection switch 16 is opened to detect the voltage stored in the liquid crystal capacitor 2a from the inspection terminal 17. If the voltage can be detected at that time, it can be judged that the gate driver 6 and the data driver 5 are operating normally, and that the scanning line 4 and the data line 3 from the gate driver 6 or the data driver 5 to the TFT 1a are not broken and are acceptable.

Incidentally, the reset of the liquid crystal capacitors 2a may be performed by the data driver 5 in place of the reset by the reset data input terminal 13.

-Sixteenth Embodiment-

FIG. 22 shows a liquid crystal display substrate according to the sixteenth embodiment of the present invention. The point of the sixteenth embodiment differing from the fifteenth embodiment (FIG. 21) is explained. In addition to the group of the TFTs 1a at the left end (input end) in the pixel region 7, a group of TFTs 1b at the right end (output end) are used as inspection switching elements. Sources of the TFTs 1b are connected to the electrode 8 on the opposite substrate via liquid crystal capacitors 2b.

In addition to the data line 3 at the left end of the data driver 5, to the data line 3 at the right

end, the inspection terminal 17 is connected via the inspection switch 16, and the reset data input terminal 13 is connected via the reset switch 11.

The inspection method is explained. The charges in the liquid crystal capacitors 2a or 2b are removed through use of the reset switches 11 as in the fifteenth embodiment. Then, the gate driver 6 turns on the TFT 1a and the TFT 1b of the pixels to be inspected. During a period during which the TFT 1a and the TFT 1b are on, the data driver 5 supplies voltage to the liquid crystal capacitors 2a and 2b to charge them. Subsequently, the inspection switches 16 are opened to detect the voltages stored in the liquid crystal capacitors 2a and 2b from each of the respective inspection terminals 17. This also enables the inspection of a break in the scanning line 4 in the pixel region 7.

-Seventeenth Embodiment-

FIG. 23 shows a liquid crystal display device according to the seventeenth embodiment of the present invention. The seventeenth embodiment is a liquid crystal display device using the liquid crystal display substrate of the eleventh embodiment. The inspection switching elements 9, the capacitors 30, and the pixel region 7 are provided on a substrate 51. The common electrode 8 is provided on an opposite substrate 52. The substrate 51 and the opposite substrate 52 hold liquid crystal (capacitors

2) sandwiched therebetween, which in turn is sealed by a sealing part 20. The sealing part 20 is provided between the pixel region 7 and the inspection switching elements 9. The capacitors 30 connected to the inspection switching elements 9 are not the liquid crystal capacitors but newly formed capacitors because the capacitors 30 can not use the liquid crystal since they are outside the sealing part 20.

-Eighteenth Embodiment-

FIG. 24 shows a liquid crystal display device according to the eighteenth embodiment of the present invention. The point of the eighteenth embodiment differing from the seventeenth embodiment (FIG. 23) is explained. All of the above-described elements except for the common electrode 8 are provided on a substrate 53. The common electrode 8 is provided on an opposite substrate 54. The substrate 53 and the opposite substrate 54 hold the liquid crystal (capacitors 2) sandwiched therebetween, which in turn is sealed by the sealing part 20. The sealing part 20 is provided at the outer periphery of the liquid crystal display device. Since the inspection switching elements 9 are provided inside the sealing part 20, the inspection pixels are used as the inspection switching elements 9. The sources of the inspection switching elements 9 are connected to the

electrode 8 on the opposite substrate via the liquid crystal capacitors 2.

In the case of the seventeenth embodiment (FIG. 23), since the gate driver 6, the data driver 5, and the inspection switching elements 9 are provided outside the sealing part 20, they are susceptible to breakage due to corrosion or other external factors. In the eighteenth embodiment, however, the gate driver 6, the data driver 5, and the inspection switching elements 9 can be protected since they are provided inside the sealing part 20. Further, the storable capacity of the inspection capacitor 30 is small in the seventeenth embodiment, but that of the liquid crystal capacitor 2 can be large in the eighteenth embodiment by virtue of use of the liquid crystal.

-Nineteenth Embodiment-

FIG. 25 shows a liquid crystal display device according to the nineteenth embodiment of the present invention. The point of the nineteenth embodiment differing from the eighteenth embodiment (FIG. 24) is explained. A light shielding region (black matrix) 21 is provided at a part of the substrate 54 except for the pixel region 7.

Because the inspection pixels 15 (inspection switching elements 9) become an obstacle during normal operation, black data is written in the inspection pixels 15 to bring them into a state

without producing display during the normal operation. However, it is difficult to bring the inspection pixels 15 into a complete black display, which causes a not slight decrease in contrast. The provision of the light shielding region 21 at the part covering the inspection pixels 15 as in this embodiment enables a complete black display of the inspection pixels 15, thereby preventing a decrease in contrast.

A method of forming a light shielding film by processing is preferable as a light shielding method. This method has a high light shielding accuracy. Other than the above, there is a light shielding method with a mechanical structure (light shielding tape, bezel or the like).

According to the first to nineteenth embodiments, judgement can easily be made whether the liquid crystal display substrate, as it is, passes or fails an inspection, which enables the period required for the inspection to be made short as compared to the conventional inspection method, and the disposal of a member attendant on the panelizing test becomes unnecessary, which leads to cost reduction.

It should be noted that any of the above-described embodiments is just a concrete example for carrying out the present invention, and therefore the technical range of the present invention is not intended to be interpreted in a narrow sense by them. In other words, the present invention can be realized

in various forms without departing from its technical idea or its primary characteristics.

As has been described, the provision of the first and second inspection circuits on the liquid crystal display substrate enables, before unitization of the liquid crystal display device, inspection of breaks in the data lines, short circuits between adjacent data lines, breaks in the scanning lines, short circuits between adjacent pixels, short circuits to other signal lines, and the like. The separation of the first inspection circuit after the inspection enables the data driver to be connected to the liquid crystal display substrate, thereby providing a liquid crystal display device at a lower cost.

10035044-121801